

Impacts of the renewable energy law on the developments of wind energy in Turkey



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ABSTRACT

Wind energy, which is one of the most significant renewable energy sources in the world, may be a promising alternative for Turkey in both short and long term. Although wind energy applications in Turkey began around the beginning of the millennium, significant progress did not occur until after the passage of the 2005 “Renewable Energy Law”. That law included a series of policies for the introduction of tariff support for electricity produced by renewable sources. The unit capacity of wind power and wind energy utilization has since grown dramatically. As a result, the Turkish wind power industry has undergone rapid developments, with further acceleration of technology occurring in 2012. In this study, wind energy potential and wind energy projects of Turkey are investigated and presented in detail. Furthermore, current impacts of renewable energy law announced in May 2005 are emphasized. Planned and constructed wind energy projects in Turkey are also presented.

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1. Introduction

The geographical coordinates of Turkey is 36°–42' north latitude and 26°–45' east longitude. Turkey has a total area of 814,578 km² and it is located between Europe and Asia like a

bridge and surrounded by seas around three sides. Turkey is a rapidly growing country and on the other hand both its population and economy are expanding each year so its energy demand increases correspondingly and this increasing demand has to be met to keep sustainable development in the economy and raising living conditions of people [1,2]. By the way, energy plays a vital role in socio-economic development and raising standards of livings. Although Turkey has many energy sources, it is a big energy importer. Turkey has a lot of potential to supply its own energy, which could be put to use in order to avoid this energy dependency. Turkey lacks large natural gas, coal and oil reserves:

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Table 1
Turkey's energy consumption by resources [3,4].

Type of resources (ktoe)	2006	2010	2015	2020
Hard coal	14,721	17,282	26,884	48,156
Lignite	11,188	18,001	24,190	32,044
Asphaltite	259	301	301	301
Oil	32,551	41,184	50,420	60,918
Natural gas	28,867	37,192	44,747	51,536
Nuclear	0	0	8,229	8,229
Wind	11	421	571	721
Solar	403	495	605	862
Fuel wood	4023	3383	3075	3075
Animal and vegetable residues	1146	1034	926	850
Geothermal (heat)	1081	1750	2836	4584
Geothermal (electricity)	330	330	330	330
Hydraulic	3556	4903	7060	9419
Growth rates (%)		29	35	31

Turkey's Gross Electricity Generation By Primary Energy Resources (2012)

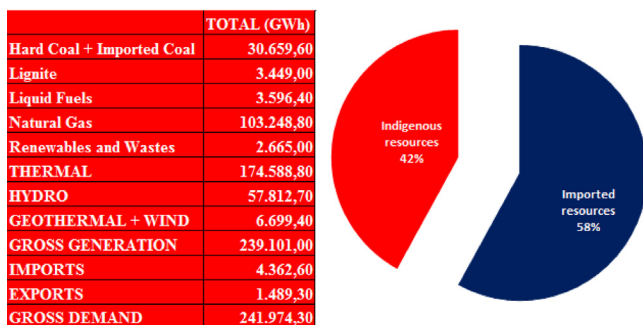


Fig. 1. Turkey's gross electricity generation by primary resources (2012).

over 75% of energy demand is imported and indigenous sources only meet 40% of Turkey's electricity production. However, Turkey has a large potential for renewable energies. Table 1 shows Turkey's current and future energy consumption forecast (taken from Ministry of Energy and Natural Resources of Turkey) by resources [3,4].

The average annual increase in the rate of electricity production was approximately 8.7% for 1970–2008. Therefore, meeting the rapid increase in electrical energy demand and finding solutions for energy security problems are the main dilemma in Turkey. To overcome this problem, it is crucial to increase the rate of indigenous and renewable sources in electrical energy production. Among renewable energy sources, wind energy is one of the fastest growing energy sources, and is regarded as an important alternative to traditional power generating sources in Turkey. Moreover, wind energy is an abundant, clean, affordable, environmentally preferable, elegant, and inexhaustible energy source [5].

Despite the fact the first wind turbine started operation in Turkey as early as 1998; actual progress in the market has started in 2006 after the adoption of Renewable Energy Law on 18 May 2005. Although the law is an important step towards the renewable energy implementations, it does not set a target for electricity generated from renewable sources. In 2006 a total of 56 MW capacity of wind turbines were erected, followed by a further 148 MW in 2007. In the end of 2008 the installed wind capacity in Turkey has reached to 433 MW with an increase of 286 MW. According to latest figures released from Turkish Wind Energy Association (TWEA) in March 2012 there are 49 wind farms with an installed capacity of 1803 MW operating in Turkey [6–8].

In this study, wind energy potential and today's and future's wind energy projects of Turkey are investigated and presented in detail. Furthermore, Renewable energy law released at the date of

May 2005 is analyzed in detail because after that date wind energy movement in Turkey has shown a considerable increase. Therefore, current impacts of Renewable energy law released at the date of May 2005 on the wind energy development in Turkey are searched from many aspects. Besides, the planned and constructed wind energy projects in Turkey are presented to display affirmative sides of the law.

2. Past, present and future of renewable energy in Turkish electricity sector

Electricity energy demand of Turkey regularly increases in each year with the contribution of increasing population and industrialization. Fig. 1 presents Turkey's gross electricity generation by primary energy resources in 2012.

According to Fig. 1, it is fairly obvious that Turkey is still a country heavily depending on the imported fossil energy resources, but a considerable and continuous increase in the renewable's share in the total electricity generation, as clearly seen in Figs. 2 and 3, makes us hopeful for future. With the supports of both the current energy policies and also a newly emerged understanding for energy in Turkey, exploiting indigenous renewable energy resources may be a valuable alternative way of meeting such an energy demand of Turkey. Concordantly, all the national politics and laws published by the current government have played an important role in the development of this new understanding concerned with the energy. According to the "Revised strategy Paper" which was published in 2009, Turkey's

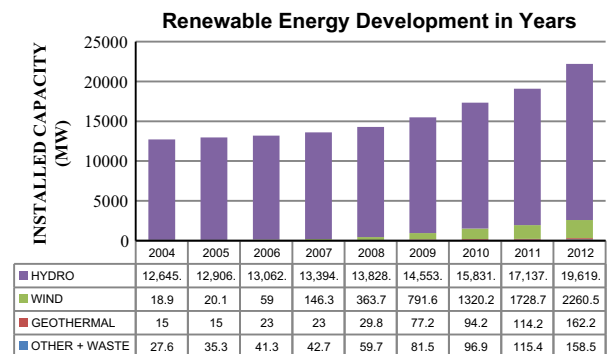


Fig. 2. Renewable energy development in Turkey (2012).

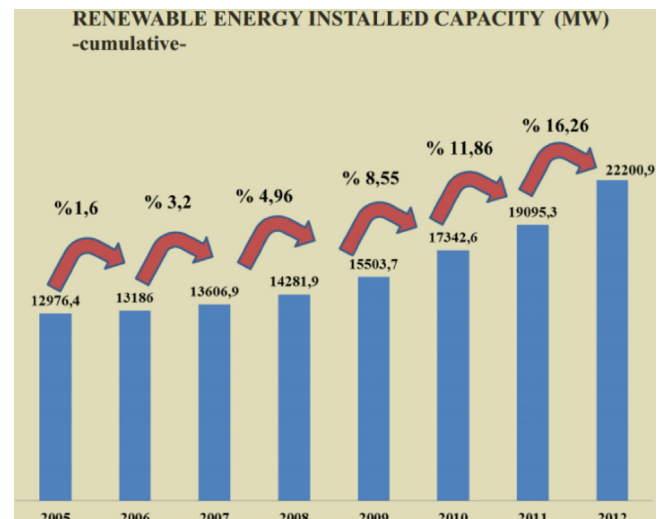


Fig. 3. Annual variation in the cumulative installed capacity of renewable energy.

energy targets in 2023 (Turkey will celebrate the 100th anniversary of the republic) are presented as follows [9]:

- 30% of total electricity production from renewable resources
- installed capacity for wind energy 20,000 MW
- installed capacity for solar energy (min) 3000 MW
- installed capacity for geothermal energy 650 MW
- the whole economically usable hydropower potential of Turkey will be provided for electricity generation until 2023

Firstly, it should be underlined that since Turkey has got sufficient renewable and indigenous hydro, wind, geothermal, biomass and solar energy potentials as seen in Table 2, it can achieve them easily if it continues being decisive in doing all the things which have been done after 2006. Regarding the energy targets in 2023, especially, two important outputs should be highlighted: (i) the installed wind energy capacity would be about ten times more than one in 2012, (ii) minimum installed solar energy capacity is estimated to be 3000 MW though there is now no electricity generation from solar energy.

So far, it has been underlined that Turkey has a big energy potential for various renewable energy resources, for not only one energy resource and that such a renewable energy potential can be trusted on supplying a big portion of the energy demand. Now, considering the renewable energy development between 2004 and 2012, it is clearly seen that there is no more renewable energy development at the beginning of this period, but after 2006 (when government published some laws which have been useful for increasing utilization of the renewable energy potential) there is a dramatical increase in exploiting renewable energy resources; share of renewable energy installed capacity in the total capacity increases, especially share of the wind energy, for instance, installed wind energy capacity increased from 59 MW in 2004–2260.5 MW in 2012.

Summarily, considering renewable energy development in Turkey in the last decade as seen in Fig. 3, it is understood that rate of increase in the renewable energy installed capacity is also more likely getting higher in the following years. Therefore, this gives us a huge hope for achieving the targets for 2023.

3. Wind energy development in the world

The world market for wind turbines set a new record in the year 2011 and reached a total size of 42 GW, after 37.6 GW in 2010 [10]. 9616 MW of wind power capacity (worth some €12.6 billion) was installed in the EU during 2011, a similar figure to the previous year (9648 in 2010). Wind power accounted for 21.4% of total 2011 power capacity installations.

Table 2
Renewable energy resource potential of Turkey [9].

Hydro	GWh/year	135
Wind	Potential	48,000
	2023 Target (MW)	20,000
	Under operation (MW) (April 2012)	2,260, 5
	Electricity production (2012)	5,581, 5 GWh
Geothermal	MWhth/year	31,500
	Electricity production (2012)	850 GWh
	MW in operation	162, 2
	MW under const.	120
Biomass	Mtoe/year	8
	MW in operational	158, 5
Solar	Mtoe/year	35
	GWh/year technically	380

Renewable power installations accounted for 71.3% of new installations during 2011 32,043 MW of a total of 44,939 MW of new power capacity. More renewable power capacity was installed during 2011 than any other years, an increase of 37.7% compared to 2010. Also more power capacity was installed in 2011 than ever before, an increase of 3.9%. Annual installations of wind power have steadily increased from 814 MW to 9,616 MW between 1995 and 2011 an annual average market growth of 15.6%. A total of 93,957 MW is now installed in the European Union, an increase in installed cumulative capacity of 11% compared to the previous year. Germany remains the EU country with the largest installed capacity, followed by Spain, France, Italy and the UK. Growth in onshore installations in Germany and Sweden, and offshore in the UK – together with continuing strong performance from some emerging onshore markets in Eastern Europe – have more than offset the fall in installations in mature markets such as France and Spain. The wind capacity installed by the end of 2011 would, in a normal year, produce 204 TWh of electricity, representing 6.3% of electricity consumption – up from 5.3% the year before [11].

4. Wind energy potential in Turkey

Wind energy is actually a promising energy source that can meet the energy demand of Turkey in the future. Turkey has a significant wind energy potential in compared to some of the other European countries. The values of the technical wind energy potential of European countries are given in Table 3. As shown in Table 3, Turkey has the highest share of technical wind energy potential in Europe [7,12–15].

In 2002, Turkey Wind Map was prepared from Turkish State Meteorological Service. The results of the wind map showed that the economic potential was 10,000 MW and the technical potential was 88,000 MW. Further research to determine the technical wind potential of Turkey was carried out in 2006 by the General Directorate of Electrical Power Resources and Development Administration. The Wind Energy Potential Atlas (REPA) was prepared by numerical weather prediction methodology at $200 \times 200 \text{ m}^2$ resolution for different heights [16]. Wind energy potential at 50 m above ground level in land regions was calculated as 131,756 MW, which is equivalent to a wind power density greater than 300 W/m^2 [17].

Table 3
The values of the technical wind energy potential of European countries [7].

Country	Territory thousand km ²	Side potential km ²	Technical potential	
			MW	TWh/yr
Turkey	781	9960	88,000	166
UK	244	6840	57,000	114
Spain	505	5120	43,000	86
France	547	5080	42,000	85
Norway	324	4560	38,000	76
Italy	301	4160	35,000	69
Greece	132	2460	22,000	44
Ireland	70	2680	22,000	44
Sweden	450	2440	20,000	41
Iceland	103	2080	17,000	34
Denmark	43	1720	14,000	29
Germany	357	1400	12,000	24
Portugal	92	880	7000	15
Finland	337	440	4000	7
Netherlands	41	400	3000	7
Austria	84	200	2000	3
Belgium	31	280	2000	5
Switzerland	41	80	1000	1
Luxembourg	3	0	0	0

Turkey has a significant wind energy potential because of its geographical characteristics, such as its shoreline and mountain-valley structures[18]. Fig. 4 shows the annual wind power density at a height of 50 m [19]. From Fig. 4, it can be easily seen that wind sources in Turkey are concentrated in the western and southern regions of Turkey.

Sea fronts of the Aegean, Marmara, Mediterranean, and Black Sea, and some places of the Southeast Anatolian belt have a high wind potential, with an average speed of 4.5–10 m/s[20]. Annual average wind speed and annual average wind power density of all regions of Turkey are shown in Table 4 [7,14,15].

According to the Wind Energy Potential Atlas, prepared by the General Directorate of Electrical Power Resources Survey and Development Administration, wind speed at 50 m height and outside the residential areas, at Marmara, West Black sea, and the East Mediterranean coasts and inner parts of these regions are 6.0–7.0 and 4.5–5.0 m/s, respectively. The north-west Aegean coasts are also 7.0–8.5 m/s, and in the inner parts are 6.5–7.0 m/s[14].

5. Legal framework of Turkish energy sector

As explained before, Turkey is very rich for various renewable energy resources. However, this potential has not been utilized so far, and the installed capacity of renewable was so less compared to its potential before 2006. It is the fact that in order to bring the utilization of the renewable energy potential in Turkey to the reasonable level in MW and also to take the energy investors' attention, government must have given considerable performances such as making legislative regulations providing convenience for energy investments. Thus, the current Turkish government has prepared the necessary legislative regulations concerned with energy, especially renewable energy and published some useful laws: Renewable energy law and electricity market law. After launching to apply them in Turkey, Turkish energy sector has stimulated considerably.

5.1. Electricity market law

In March 2001, the Turkish government enacted The Electricity Market Law (EML) with the law no. 4628 which sets the stage for liberalization of power generation and distribution activities. The new law also created the Energy Market Regulatory Authority (EMRA) to take the necessary measures to promote the utilization

of renewable energy resources, including the setting of tariffs, issuing licenses and assuring competition. This legislation generated two policies related to renewable energy:

- Renewable energy facilities are only required to pay 1% of the total license fee or the license for construction and are exempted from the annual license fee for the first eight years following the completion date of the facilities stated in their licenses.
- The auto-producers which generate electricity from renewable energy resources may purchase electricity from private sector wholesale companies under certain conditions whereas the other auto-producers are not entitled to do so. Moreover it is stated in the Article 38 of Electric Market Licensing Regulation (EMLR) that TEIAS and/or the distribution companies are required to give priority status to the facilities generating electricity from renewable energy resources in terms of their connection to the transmission and/or distribution systems [6,21–23].

5.2. Renewable energy laws

Law on utilization of renewable energy sources for the purpose of generating electrical energy (Law No. 5346) passed in 2005. This law is to expand the utilization of renewable energy sources for generating electric energy, to benefit from these resources in a secure, economic and qualified manner, to increase the diversification of energy resources, to reduce greenhouse gas emissions, to

Table 4

Annual average wind speed and annual average wind power density for all regions of Turkey measured at the height of 10 m [7,14,15].

Region	Annual average wind density (W/m ²)	Annual average wind speed (m/s)
Marmara	51.9	3.3
Southeast Anatolia	29.3	2.7
Aegean	23.5	2.6
Mediterranean	21.4	2.5
Black Sea	21.3	2.4
Central Anatolia	20.1	2.5
East Anatolia	24.0	2.5

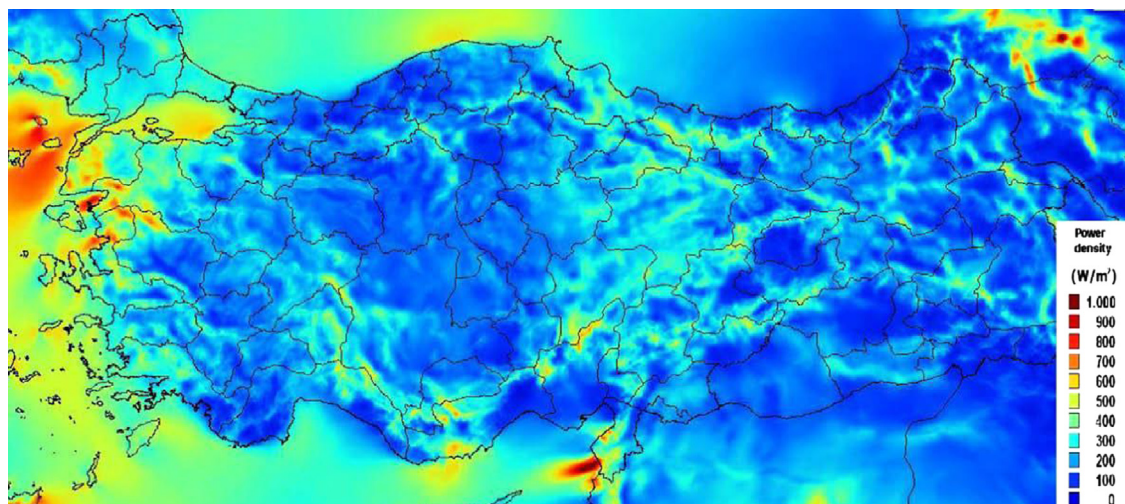


Fig. 4. The annual wind power density at a height of 50 m in Turkey.

assess waste products, to protect the environment and finally to develop the related manufacturing industries for realizing these objectives [24].

A legal entity, holding a generation license shall be awarded a “Renewable Energy Source Certificate” (RES Certificate) by Energy Market Regulatory Authority (EMRA), in order to identify and monitor the type of the source in purchasing and selling electric energy generated from renewable energy sources in domestic and international markets. The procedures and principles of RES Certificate shall be stipulated by a regulation. Legal entities holding licenses shall be subject to the following principles of implementation within the scope of this law:

- a) Legal entities holding a retail sale license, shall buy electrical energy from power plants generating electrical energy from renewable energy resources within the scope of this law, which are holding a RES certificate and which have not completed in 10 years of operation, in accordance with the principles set forth in this Article [23].
- b) The information relating to the amount of RES-certified electrical energy available for the implementations within the scope of this Law should be published by the Energy Market Regulatory Authority (EMRA) annually. Each of the legal entities holding a retail sale license shall purchase the amount of RES-certified electrical energy in accordance with the proportion of the energy amount they sold within the previous calendar year to the total electrical energy amount they sold in the country [24].
- c) The price to be applicable to the electrical energy to be purchased within the scope of this law, for each year should be the electricity average wholesale price in Turkey for the previous year as determined by EMRA. However, such applicable price may not be less than the Turkish Lira equivalent of 5 Euro Cent/kWh and may not exceed the Turkish Lira equivalent of 5.5 Euro Cent/kWh. However, legal entities that hold licenses based on renewable energy resources and which have the opportunity to sell above the limit of 5.5 Euro Cent/kWh in the market should benefit from this opportunity. The implementations within the scope of this Article shall cover the plants that are put into operation before 31st of December 2011. However, the Council of Ministers may extend the expiration date to 2 years at the most, provided that such extension is published in the Official Gazette of Republic of Turkey until 31 December 2009 [24].
- d) Furthermore, Turkey's renewable energy generation targets and system of feed-in tariffs, which provide a purchase guarantee for renewable energy generation, act as the main policy incentives for renewable energy deployment.

Turkish Parliament of the Law amended the Law on Utilization of Renewable Energy Resources in Electricity Generation with law no: 5343. The new law is called Amendment Law, with law no: 6094 which was enacted 29 December 2010, announced in the Official Gazette dated 8 January 2011. The Amendment Law introduces considerable amendments to improve the incentive mechanism under the Renewable Energy Law and encourage renewable energy investment opportunities in Turkey.

New tariffs have been introduced for the sale of electricity by generation facilities based on renewable energy resources. According to the Amendment Law, the applicable sale tariffs within the scope of the RES Support Mechanism are as follows:

- Wind power plants: \$0.073/kWh
- Hydroelectric power plants: \$0.073/kWh
- Geothermal power plants: \$0.105/kWh
- Biomass power plants: \$0.133/kWh
- Solar power plants: \$0.133/kWh

A generation licensee within the scope of the RES Support Mechanism can only benefit from the above sale tariffs for a maximum term of 10 years from its operation date. The Council of Ministers will determine the sale tariffs applicable to generation plants starting operations after 31 December 2015 but such tariffs cannot exceed the rates above.

An additional incentive has also been introduced to promote the use of Turkish equipment. Accordingly, if the mechanical and electromechanical components of a power plant subject to the RES Support Mechanism and which commenced operations before 31 December 2015 are manufactured in Turkey, the above sale tariffs will be increased in the amounts set out under the Renewable Energy Law. A generation licensee will be able to benefit from this incentive for five years starting from the operational date of the power plant [25].

Turkey's main targets and support policies for renewable energy are summarized as follows:

General targets

- 30% of renewable energy in electricity generation by 2023.
- Indicative split:
 - Wind: 10 GW (2014), 20 GW (2023)
 - Hydropower: “entire potential”, ~40 GW (2023)
 - Geothermal: 300 MW (2014), 600 MW (2023)

Financial supports

- Feed-in tariffs: It was established in the Renewable Energy Law 2010 and applied to bioenergy, geothermal, hydropower, solar and wind for the first ten years of operation. But, it must be commissioned by 31 December 2015. Tariff supplements are available for domestic equipment use, as defined before.
- Industrial Development Bank of Turkey (TSKB): It supplies the low-interest loans to a number of renewable projects.

Other support

- Ministry of Energy and Natural Resources Strategic Plan 2010
- Grid access and priority dispatch: Renewable energy projects have priority for grid connection.

6. Assessment and utilization of wind energy in Turkey

In Turkey, it is possible to see a few private sector companies are investing on energy production with wind power lately. Due to legal restrictions, in order to produce electricity by wind turbines, it is necessary to get permission from the Ministry of Energy. The machinery used in WECSs is generally imported since Turkey has no industry on manufacturing these systems. At regions having high wind energy potential, supplying energy for agricultural area like irrigating systems and domestic use in farms can be prior advantages. Output can be satisfactory since the need of energy is quite low at rural areas and the connection lines are expensive to install. Considering the simplicity and the smaller size of wind energy systems, they are economically feasible to install and run. For the areas that need small amounts of energy, energy production and supply can be overcome with smaller investment [20]. Table 5 presents some characteristics of the current wind energy projects in operation in Turkey.

6.1. Before renewable energy law

There were few installed wind power plants before the renewable energy laws were passed in 2005. They are summarized as following. The first Turkish wind turbine was constructed in Cesme by the Vestas company in 1986, and it was realized at Cesme Altinyunus Resort

Table 5

Some characteristics of the current wind energy projects in operation in Turkey.

Company name	Project name	Installed capacity [MW]	Number of turbines	Turbine brand	Location
Alize En. El. Ür. A.Ş.	Çeşme RES	1.5	3	ENERCON	Izmir
Ares Alaçatı Rüz. En. San. Tic. A.Ş.	Ares RES	7.2	12	VESTAS	Izmir
Bores Bozcaada Rüz. En. San.Tic. A.Ş.	Bozcaada RES	10.2	17	ENERCON	Çanakkale
Sunjüt Suni Jüt San. Tic. A.Ş.	Sunjüt RES	1.2	2	ENERCON	Istanbul
Yapısan El. Ür. A.Ş.	Bandırma RES	35	22	GE(30 MW)+NORDEX (5 MW)	Balıkesir
Teperes El. Ür. A.Ş.	Tepe RES	0.85	1	VESTAS	Istanbul
Anemon En. El. Ür. A.Ş.	İntepe RES	30.4	38	ENERCON	Çanakkale
Doğal En. El. Ür. A.Ş.	Burgaz RES	14.9	18	ENERCON	Çanakkale
Deniz El. Ür. Ltd. Şti.	Karakurt RES	10.8	6	VESTAS	Manisa
Doğal En. El. Ür. A.Ş.	Sayalar RES	34.2	38	ENERCON	Manisa
Lodos El. Ür. A.Ş.	Kemerburgaz RES	24	12	ENERCON	Istanbul
Dares Datça Rüz. En. Sant. San. ve Tic. A.Ş.	Dares Datça RES	29.6	36	ENERCON	Muğla
Innores El. Ür. A.Ş.	Yuntdağ RES	57.5	23	NORDEX	Izmir
Deniz El. Ür. Ltd. Şti.	Sebenoba RES	30	15	VESTAS	Hatay
Baki El. Ür. Ltd. Şti.	Şamlı RES	113.4	43	VESTAS	Balıkesir
Sanko Rüz. En. San. ve Tic. A.Ş.	Çatalca RES	60	20	VESTAS	Istanbul
Alize En. El. Ür. A.Ş.	Sarıkaya RES	28.8	15	ENERCON	Tekirdağ
Alize En. El. Ür. A.Ş.	Çamseki RES	20.8	11	ENERCON	Çanakkale
Alize En. El. Ür. A.Ş.	Keltepe RES	20.7	23	ENERCON	Balıkesir
Ayen En. A.Ş.	Akbük RES	31.5	15	SUZLON	Aydın
AkEn. El. Ür. A.Ş.	Ayyıldız RES	15	5	VESTAS	Balıkesir
Alize En. El. Ür. A.Ş.	Çataltepe RES	16	8	ENERCON	Balıkesir
Alize En. El. Ür. A.Ş.	Kuyucak RES	25.6	14	ENERCON	Manisa
Kores Kocadağ Rüz. En. Sant. Ür. A.Ş.	Kores Kocadağ-2 RES	15	6	NORDEX	Izmir
Boreas En. Ür. San. ve Tic. Ltd. Şti.	Boreas 1 Enez RES	15	6	NORDEX	Edirne
Bergama RES En. Ür. A.Ş.	Aliağa RES	90	36	NORDEX	Izmir
Bilgin Rüz. Sant. En. Ür. A.Ş.	Soma RES	90	36	NORDEX	Manisa
As Makinsan En. El. Ür. San.Tic. A.Ş.	Bandırma-3 RES	24	10	NORDEX	Balıkesir
Bakras Enerji Elektrik Ür. ve Tic. A.Ş.	Şenbük RES	15	5	VESTAS	Hatay
Akdenez El. Ür. A.Ş.	Mersin Mut RES	33	11	VESTAS	Mersin
Sabaş El. Ür. A.Ş.	Turguttepe RES	24	12	VESTAS	Aydın
Doruk En. Ür. San. Tic. A.Ş.	Seyitali RES	30	15	ENERCON	Izmir
Kardemir Haddecilik San.Tic. Ltd.Şti.	Bozyaka RES	12.5	6	NORDEX	Izmir
Akhisar Rüz. En. El. Ür. San. Ltd. Şti.	AkRES	45	18	NORDEX	Manisa
Alentek En. A.Ş.	Susurluk RES	45	18	NORDEX	Balıkesir
Enerjisa En. Ür. A.Ş.	Çanakkale RES	29.9	13	SIEMENS	Çanakkale
Ayres Ayvacık El. Ür. Sant. Ltd. Şti.	AyRES	5	3	VESTAS	Çanakkale
Galata Wind En. Ltd. Şti.	Şah RES	93	31	VESTAS	Balıkesir
ABK En. Ür. San. ve Tic. A.Ş.	Söke-Çatalbük RES	30	15	GAMESA	Aydın
Pem En. A.Ş.	Killik RES	40	16	NORDEX	Tokat
Mare Manastır Rüz. En. San. Tic. A.Ş.	Mare Manastır RES	39.2	49	ENERCON	Izmir
Rotor El. Ür. A.Ş.	Gökçedağ RES	135	54	GE	Osmaniye
Ütopya En. Ür. San. Tic. A.Ş.	Düzova RES	30	12	GE	Izmir
Mazı-3 Rüz. En. Sant. El. Ür. A.Ş.	Mazı-3 RES	30	12	NORDEX	Izmir
Belen El. Ür. A.Ş.	Belen RES	36	12	VESTAS	Hatay
Borascio En. ve Kim. San. Tic. A.Ş.	Bandırma RES	60	20	VESTAS	Balıkesir
Ziyaret RES El. Ür. San.Tic. A.Ş.	Ziyaret RES	57.5	23	GE	Hatay
Garet En. Ür. ve Tic. A.Ş.	SaRES	22.5	9	GE	Çanakkale
Soma En. El. Ür. A.Ş.	Soma RES	140.4	119	ENERCON	Manisa
TOTAL		1806.2			

Hotel (The Golden Dolphin Hotel). In this turbine the height of the center of the blade is 24.5 m and the blade diameter is 14 m. It provides an electric power of 55 kW at a wind speed of 12 m/s and generates 100,000 kWh electricity energy under Cesme weather conditions. The resort hotel, with 1000 beds, consumes of about 3 million kWh of electrical energy annually, while the windmill installed produces 130,000 kWh/yr, approximately [15,26,27]. Between 1986 and 1996, there were some attempts to generate electricity from wind, but they were never successful. Although the first Turkish wind turbine was constructed in Cesme, the development of modern Turkish wind power engineering began on November 21, 1998 when the first 3 Enercon E-40 model wind turbines of 500 kW each began to operate at Alacati, Izmir. The blade diameter of this turbine is 40.3 m, and its annual electric energy production is estimated as 4.5 million kWh at a wind speed of 14 m/s. In November 1998, the second wind farm consisting of 12 Vestas V44/600 turbines was constructed at the same region. The turbine blade diameter is 44 m, the height of the blade center point is 45 m and they are estimated to generate 100,000 kWh of electric energy. The wind farm,

in which \$8.5 million has been invested, is estimated to repay its cost in 2.5 years [26]. The third wind farm with a total installed capacity of 10.2 MW started to operate in June 2000 at Bozcaada Island [15,27]. It includes 17 wind turbines, and each turbine has 600 kW of power. This facility generates 35 million kWh of electric energy per year. This plant has been estimated to repay its investment cost, \$13 million, in 6 years, and its life expectancy is 30–35 years [26]. The fourth wind farm of Turkey with a total installed capacity of 1.2 MW was constructed at Hadimkoy, Istanbul in 2003. It includes 2 wind turbines, and each turbine has 600 kW power. In the end of 2005, the total installed wind power capacity became 20.1 MW. Fig. 5 shows the installed wind power capacity of Turkey before renewable energy law.

6.2. After renewable energy law

From the beginning of the 21st century, the significant role of renewable energy in the national energy strategy has been identified, especially by the promulgation of “The Renewable Energy Law of Turkey”, which introduced tariff support for

electricity produced by renewable sources, in 2005. After this law, the unit capacity of wind turbine has grown from kilowatt to multi-megawatt and wind energy utilization in Turkey is progressing rapidly. Since 2006, the Turkish government has made a series of policies to promote wind energy application. As a result, wind power industry and the construction of wind farms underwent rapid development, which further accelerated technology development, in 2010 (Fig. 6) [20].

The wind farm consisting of 20 General Electric GE/1.5 MW turbines was constructed at Bandirma, Balikesir in 2006. The turbines have 54.7 m hub height and 70.5 m rotor diameter. The 52 m-high steel towers were produced by CIMITAS in Gemlik, Turkey. Bandirma wind energy power plant, not only Turkey's first privately owned and operated wind park, also had extended the current installed capacity of 20 MW in Turkey by 150% to 50 MW by itself in 2006. With an annual generation of 120 million kWh, it can supply the electricity demand of a populated town of 80,000. Among all these, with the clean power generation of Bandirma wind power plant, 70,000 t of carbon emission reduction is expected annually as well. There were five wind power plants having total 50.1 MW installed capacity and 54 wind turbines. This installed capacity has increased to 79.4 MW in

2006 and then increased to 146.3 MW in 2007. The biggest wind energy power plant (BARES wind energy plant) with 20 wind turbines and 30 MW installed power, in Turkey was built at Bandirma, Balikesir in 2006. Total wind power installed in Turkey, wind energy generating capacity, was 371.65 MW at the end of 2008. Up to the end of 2009, 26 wind farms have been built in the main land with a total installed capacity of 713.45 MW, in which the increment in 2008 was 371.65 MW. The yearly installed capacity increased 52% in 2009, and the increase in total installed capacity was about 39.9% in 2010, as shown in Fig. 3. At present, there are 44 wind power plants having total 855.05 MW installed capacity and 822 wind turbines. The biggest present wind energy power plant (GE Wind Energy Plant) with 54 wind turbines and 95 MW installed power, in Turkey was built at Osmaniye in 2010. It is expected that the installed capacity in Turkey will reach 2166.45 MW at the end of 2012 [28,29].

6.3. Future prospect

As explained in the previous sections, once the renewable energy law has been released in 2005, the number of the wind energy applications as well as the installed wind power capacity in Turkey has been increased considerably. Besides, regarding the current applications and the planned applications in future, it is strongly thought that wind energy development in Turkey will continue with the current acceleration in the following years. As shown in Fig. 7, there has been a very sharp increase in the installed wind power capacity in the over last decade, especially during 2005–2011 period, actually it increased from 19 MW to 1806 MW with the great contribution of the new renewable energy law.

When focusing on Table 6, presenting the wind power plants under construction in Turkey, following remarkable outputs can be easily drawn:

- There are 13 wind power plants under construction in Turkey, with a total installed capacity of approximately 517 MW.
- They will be installed in five different geographical regions of Turkey:
 - Mediterranean region including two cities, Hatay and Mersin, with a total installed capacity of 63 MW
 - Aegean region including four cities, Aydin, Balikesir, Izmir and Mugla, with a total installed capacity of almost 250 MW.
 - Central Anatolian region including only one city, Kayseri, with a total installed capacity of 72 MW.

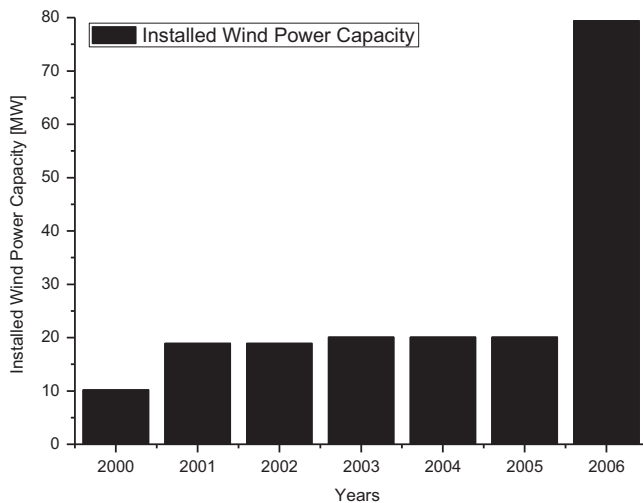


Fig. 5. Installed wind power capacity before renewable energy law.

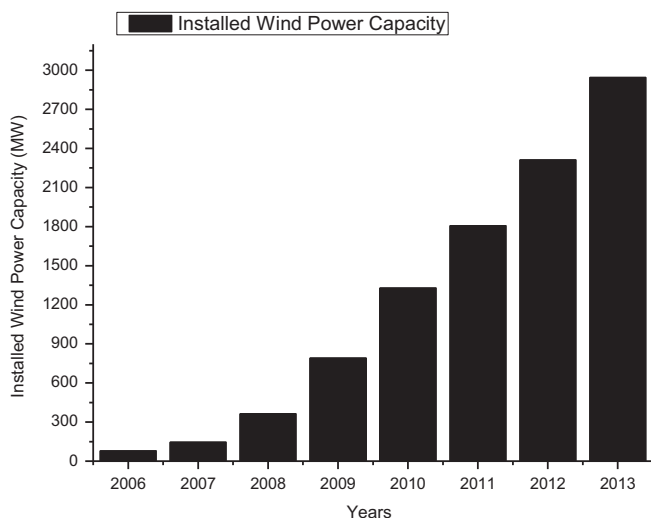


Fig. 6. Installed wind power capacity after renewable energy law.

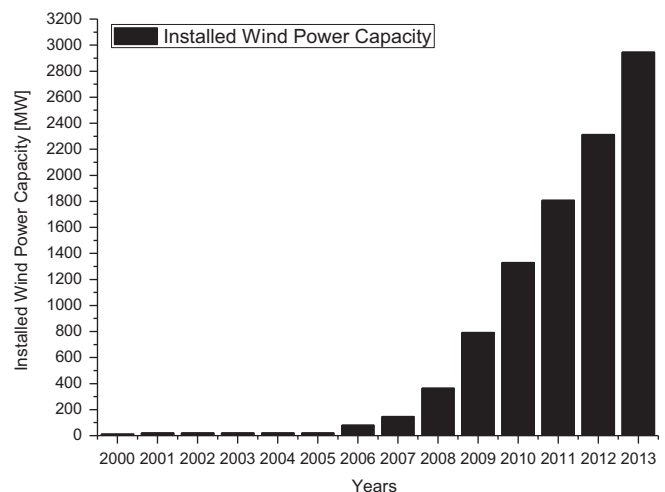


Fig. 7. Installed wind power capacity in Turkey.

Table 6

Wind power plants under Construction in Turkey.

Company name	Project name	Installed capacity [MW]	Number of turbines	Turbine brand	Location
Eolos Rüz. En. Ür. A.Ş.	Senkoy RES	27	9	ALSTOM WIND	Hatay
Kiroba El. Ür. A.Ş.	Madranbaba RES	19.5	10	GAMESA	Aydin
Bares El. Ür. A.Ş.	Balıkesir RES	142.5	52	GE	Balıkesir
Garet En. Ür. ve Tic. A.Ş.	Karadağ RES	10	4	GE	İzmir
Can En. Ent. El. Ür. A.Ş.	Metristepe RES	40	16	NORDEX	Bilecik
Baktepe En. A.Ş.	Amasya RES	40	16	NORDEX	Amasya
Bangüç Bandırma El. Ür. A.Ş.	Bangüç RES	15	6	NORDEX	Balıkesir
Enerjisa En. Ür. A.Ş.	Dağpazarı RES	39	13	SIEMENS	Mersin
Ayen En. A.Ş.	Mordoğan RES	31.5	15	SUZLON	İzmir
Ayen En. A.Ş.	Korkmaz RES	25.2	12	SUZLON	İzmir
Ayen En. A.Ş.	Akbük II RES	21	10	SUZLON	Muğla
Aksu Temiz En. El. Ür. San. ve Tic. A.Ş.	Aksu RES	72	36	VESTAS	Kayseri
Kapıdağ Rüz. En. Sant. El. Ür. San. ve Tic. A.Ş.	Kapıdağ RES	34.85	17	VESTAS	Balıkesir

- Marmara region including only one city, Bilecik, with a total installed capacity of 40 MW.
- Black Sea region including only one city, Amasya, with a total installed capacity of 40 MW.
 - After completion of these projects, the installed wind power capacity will be reached up almost 2323 MW.
 - There are totally 212 wind turbines which will be erected in the projects under construction.

Considering all the current and the future wind power generation projects initiated with the assistance of the rights coming from the new renewable energy law, it is strongly supposed that Turkey will continue to exploit the wind energy potential and to sustain the wind energy development in the following years. It is noteworthy to say that, Turkey should invest more money on the wind energy applications because it has a very high wind energy potential, which is not still utilized at the desired level, therefore it should activate new, profitable wind applications and projects in the windy regions of the country to increase the utilization of the wind energy potential and electricity production from the wind.

7. Conclusions

Until the introduction of Renewable Energy Law, little importance has been given to wind power in Turkey and the installed wind capacity was only 20.1 MW at the end of 2005. After the introduction of the law followed by the amendments carried out in 2007, there has been remarkable progress in Turkish wind sector.

In Turkey, there has been a very high increase in the installed wind power capacity during the past eleven years. Especially in the period between 2005–2011, it increased almost a hundred times, reaching from 19 MW to 1806 MW, thanks to the new renewable energy law. Additionally, there are 13 wind power plants under construction in the five different geographical regions of Turkey, with the total installed capacity of approximately 517 MW. After completion of these projects, the installed wind power capacity will reach up almost 2323 MW. Regarding all the current development and the planned projects in the Turkish wind sector, it is strongly supposed that Turkey will continue to sustain the wind energy development in the following years. Meanwhile, Turkey should go on working very hard to exploit the abundant wind sources if it does not want to import the energy sources anymore and if it wants to stop its energy dependency on other countries.

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